⑫ **EUROPEAN PATENT SPECIFICATION**

�54 Apparatus for imaging a mask pattern on a substrate.

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Description

The invention relates to an apparatus for imaging a mask pattern on a substrate, which apparatus comprises a projection column provided with an optical imaging system and an optical fine-alignment system for aligning alignment marks on the substrate relative to an alignment mark in the mask, which apparatus further comprises a prealignment station for prealigning the substrate, and transfer means for transferring the substrate to a position beneath the projection column without disturbing the pre-alignment.

Such an apparatus, which is employed for the repeated projection of a reduced-scale image of an IC pattern on a semiconductor substrate, is described inter alia in the article "Automatic Alignment System for Optical Projection Printing", in "IEEE Transactions on Electron Devices", Vol. ED-26, No. 4, April 1979, pages 723—728. The fine-alignment system of this apparatus enables a substrate to be aligned relative to the mask with an accuracy of the order of 0.1 μm. Fine-alignment is effected fully automatically and comparatively rapidly, within 1 to 2 seconds, so that a large number of substrate wafers can be passed through the imaging apparatus and exposed in a short time. The alignment range of the fine-alignment system is relatively small, for example ±40μm, so that pre-alignment of the substrate is necessary. In order to ensure that this pre-alignment does not lead to a reduction of the speed with which the substrate wafers are fed through the imaging apparatus the apparatus comprises a pre-alignment stations next to the projection column. During fine-alignment and exposure of a first substrate wafer in the projection column the next substrate wafer can be pre-aligned in the pre-alignment station, so that in principle two steps are carried out at the same time.

Pre-alignment can be effected by means of a microscope by means of which it is ascertained whether a substrate wafer is positioned correctly relative to a fixed reference, such as cross-hairs, in the apparatus. Depending on the positional error thus found the wafer position is corrected manually. This non-automatic pre-alignment takes a comparatively long time and requires much skill from the operator.

Automatic pre-alignment is possible if the substrate table has been provided with stops against which the substrate wafer must be positioned. The problem may be encountered that the edge of the substrate wafer is not always well-defined, so that the required pre-alignment accuracy cannot be attained, which results in incorrect alignment of the substrate wafer by the fine-alignment system.

The present invention aims at providing an imaging apparatus in which pre-alignment is effected automatically and very accurately. To this end the apparatus in accordance with the invention is characterised in that the pre-

alignment station comprises two optical systems for imaging the two alignment marks on the substrate onto two composite radiation-sensitive detectors, the combined output signals of the subdetectors of each detector being a measure of the alignment of the corresponding alignment mark relative to the detector.

The invention is based on the recognition of the fact that the alignment marks intended for fine-alignment inside the projection column are also very suitable for the purpose of pre-alignment outside the projection column. As two alignment marks and two composite detectors are used, it is not only possible to pre-align the marks themselves in two mutually perpendicular directions, but it is also possible to establish the orientation of a connecting line between the centres of the alignment marks, i.e. to effect an angular alignment.

It is to be noted that it is known per se, inter alia from German Patent Application No. 3,235,247, to employ the same alignment marks for fine-alignment and for pre-alignment. However, in the apparatus in accordance with German Patent Application No. 3,235,247 pre-alignment is effected in the projection column and not in a separate pre-alignment station. Further, said apparatus employs the same optical systems for fine-alignment and pre-alignment, only the processing of the detector signals for the two types of alignment differing.

As described in the above-mentioned article in "IEEE Transactions on Electron Devices", Vol. ED-26, No. 4, April 1979, pages 723—728, it is very advantageous to employ phase gratings as alignment marks, i.e. gratings which only influence the phase of a light beam which is incident upon them, for the alignment of a substrate relative to a mask. An apparatus which is suitable for exposing a substrate with phase gratings is characterised in that the two imaging systems in the pre-alignment station are constituted by microscopes which image the phase gratings on the detectors as amplitude structures.

These microscopes may be phase-contrast microscopes which have been described comprehensively in the literature and in which radiation which has not been diffracted by the phase object passes through a quarter-wave plate. This radiation interferes with the radiation which has been diffracted by the object, so that an image is formed whose brightness variations represent the phase variations in the object. The radiation used must be highly coherent. It is then possible to utilize only a small part of the radiation emitted by a non-coherent radiation source, such as an incandescent lamp, with the result that the amount of radiation on the phase grating and hence on the detector is then small. As an alternative, a laser may be used for the radiation source. Apart from being coherent the radiation emitted by a laser is also monochromatic. However, in an apparatus for imaging a mask pattern on a substrate the use of monochromatic radiation may present problems because in each consecutive·

process step in the fabrication of an integrated circuit a thin layer of a material is deposited onto the substrate. A plurality of such thin layers may act as an anti-reflection coating for the laser radiation used. Then the detector will receive only a small amount of radiation.

A preferred embodiment of the invention in which the radiation of the pre-alignment beam covers a comparatively wide wavelength range is characterized in that the microscopes are interference microscopes which each comprise an illumination system, an imaging lens for the formation of a radiation spot on a phase grating and for imaging this grating onto a detector and a beam-splitting element for splitting the radiation from the illumination system into two subbeams in such a way that at the location of the phase grating the subbeams are shifted relative to each other over a distance equal of half the grating period of the phase grating and for combining the two sub-beams which have been reflected by the phase grating.

Since the two recombined subbeams interfere with each other the phase structure of the grating is converted into an amplitude structure. The phase grating is imaged as a bright spot on the detector, the variation of the intensity distribution over the detector being determined by the position of the phase grating, i.e. of the substrate, relative to the detector.

Preferably, the apparatus in accordance with the invention is characterized further in that the beam-splitting element is a polarization-sensitive beam splitter and in that a polarization-sensitive beam reflector is arranged between the illumination system and the imaging lens for directing radiation of a specific direction of polarization towards the phase grating and for transmitting the radiation which has been reflected by the phase grating to the detector.

The polarization-sensitive beam splitter may comprise a Savart plate or a Wollaston prism.

In accordance with a further characteristic feature of the invention the beam reflector comprises a polarization-sensitive beam-reflecting layer which comprises two sub-layers which operate in two adjacent wavelength ranges. The composite beam-reflecting layer operates over a relatively wide wavelength range.

In order to ensure that as much light as possible from the radiation source and a minimum amount of stray light reaches the phase grating and in order to suppress noise in the detector signal the apparatus in accordance with the invention may be characterized further in that the illumination system comprises a radiation source followed by a condenser lens which images the radiation source in the pupil of the imaging lens and a field aperture arranged behind the condenser lens, which aperture is imaged on the phase grating.

The apparatus in accordance with the invention may be characterized in that before the detector a beam separator having a low reflection coefficient is arranged in order to reflect a small portion of the radiation which has been reflected by the

phase grating to a reference mark, and in that there are provided optical means for visually observing the reference mark and the images of the two phase gratings superimposed on said reference mark.

The invention will now be described in more detail, by way of example, with reference to the drawings, in which

Fig. 1 shows an apparatus for imaging a mask pattern on a substrate, which apparatus is equipped with a pre-alignment station.

Fig. 2 shows a substrate grating-mark for fine-alignment, and

Fig. 3 shows an optical pre-alignment station in accordance with the invention.

Fig. 1 shows an apparatus for the repeated imaging of a mask pattern on a substrate. The principal parts of this apparatus are a projection column in which a pattern C to be imaged is mounted and a movable substrate table WT by means of which the substrate can be positioned relative to the mask pattern.

The projection column accommodates an illumination system which may comprise a lamp LA, for example a mercury lamp, an elliptical mirror EM, an element IN which is referred to as an integrator, which ensures a homogenous radiation distribution within the projection beam b, and a condenser lens CO. The beam b illuminates a mask pattern C arranged on a mask table MT. A second mask pattern T may be arranged on the mask table MT. By rotating the table MT about the spindle MA the second mask pattern can be transferred into the projection column.

The beam which traverses the mask pattern C passes through a schematically shown projection-lens system PL in the projection column, which system forms an image of the mask pattern C on the substrate W. The projection lens system, which has, for example a 5:1 reduction, a numerical aperture 0.3, and a diffraction-limited image field of a diameter of 14 mm may comprise a collimator and an objective. The collimator images the mask pattern at infinity and the objective images this pattern in its focal plane. The objective is movable in a vertical direction to follow height variations in the substrate.

The substrate W is arranged on an air-bearing supported substrate table WT. The projection lens system PL and the substrate table WT are mounted in a housing HO which at its bottom is supported on a bed plate BP for example granite, and closed at its top by the mask table MT. The apparatus further comprises a substrate changer WC which is rotatable about a spindle WCA and which is also adjustable in height. By means of this changer a substrate can be transferred from a pre-alignment station CA into the projection column. For further details of the construction and operation of the projection device reference is made to the article: "Automatic Alignment System for Optical Projecting Printing" in "IEEE Transactions on Electron Devices", Vol. ED-26, no. 4, April 1979, pages 723—728.

This article describes the method of fine-

alignment of the substrate relative to the mask. For this purpose use is made of two phase gratings in the substrate and a grating in the mask. The left-hand part of Fig. 1 shows the mask pattern C and the associated grating marks M_1 and M_2 and the right-hand part of this Figure shows the substrate W and the substrate grating marks P_1 and P_2. It also shows the repeated reduced image of the mask pattern C on the substrate.

Fig. 2 shows one of the two identical substrate phase gratings on an enlarged scale. Such a grating may comprise four sub-gratings $P_{1,a}$, $P_{1,b}$, $P_{1,c}$, and $P_{1,d}$ of which $P_{1,b}$ and $P_{1,d}$ serve for alignment in the X-direction and $P_{1,a}$ and $P_{1,c}$ for alignment in the Y-direction. The two sub-gratings $P_{1,b}$ and $P_{1,c}$ may have a grating period of, for example, 16 μm and the sub-gratings $P_{1,a}$ and $P_{1,d}$ may have a period of, for example, 17,6 μm. Each of the sub-gratings may measure, for example, 200×200 μm.

As described in the above-mentioned article in "IEEE Transactions on Electron Devices", Vol. ED-26, no. 4, pages 723—728, it is possible to attain an alignment accuracy of approximately 0.1 μm by imaging the grating marks P_1 and P_2 on the corresponding grating mark M_2 in the mask by means of a suitable optical system. However, the alignment range of this very accurate fine-alignment system is only ±40 μm, which necessitates pre-alignment. This pre-alignment is effected in a pre-alignment station referenced CA in Fig. 1. After the substrate has been pre-aligned the substrate changer, which performs a very accurately defined movement and which has been provided with mechanical means for accurately retaining the substrate during transfer, can pick up the substrate, transfer it to the substrate table in the projection column, and lower it onto the substrate table without disturbing the pre-alignment.

As is shown schematically in Fig. 1 the pre-alignment station comprises a substrate table WT' by means of which the substrate can be positioned and an optical system for determining the position of the substrate relative to a fixed reference in the pre-alignment station.

The substrate changer WC may comprise a three-limb member which is rotatable about a spindle WCA. The lower part of Fig. 1 shows this substrate changer in plan view. The limbs A_1, A_2 and A_3 are provided with substrate retaining means, not shown. The end portions of the limbs may be provided with, for example, a vacuum connection to retain the substrate on the lower surface during transfer. The substrate changer is so constructed that, if the end of the limb A_1 is situated above the substrate table WT' in the pre-alignment station, the end of the limb A_2 is situated above the substrate table WT beneath the projection column and that the end of the limb A_3 projects away from the projection column. In this position the limb A_1 can receive a pre-aligned substrate to transfer it to a position underneath the projection column, the limb A_2 can receive an exposed substrate to move it outside the apparatus, and the limb A_3 can transfer a substrate to further transport means. A substrate table may comprise a supporting member which is vertically adjustable over a distance which is larger than the thickness of the limbs of the substrate changer. This supporting member may comprise tubular supporting elements. In the position in which a substrate is situated above the substrate table WT the supporting elements support this substrate. The limb then releases the substrate, for example, by turning off the vacuum in the vacuum connection of this limb, and the arm is pivoted away. The supporting member is then moved downwards until the supporting surface is situated at the same level as the upper surface of the substrate table. Such a substrate table and substrate changer are described in the previous Netherlands Patent Application no. 8300220 (PHN 10.554).

Fig. 3 shows an optical pre-alignment system to be used in the pre-alignment station. This system comprises a first imaging system for imaging the substrate mark P_1 on a first radiation-sensitive detector D_1 and an identical second imaging system for imaging the substrate mark P_2 on the radiation-sensitive detector D_2. The first imaging system comprises an imaging lens II_1 for the formation of a radiation spot V_1 on the mark P_1 and for imaging this radiation spot on the detector D_1. Imaging must be effected in such a way that the phase structure of the grating is converted into an amplitude structure or intensity distribution.

According to the invention the alignment beam b_1 is therefore split into two subbeams $b_{1,1}$ and $b_{1,2}$ which are shifted apart over a distance equal to half a grating period at the location of the phase grating P_1, which subbeams further have such a phase difference that after they have been reflected from the substrate and have been made to interfere the grating is imaged as a bright radiation spot on the detector and the area surrounding the grating in the image is dark.

For this purpose a birefringent element, for example a Savart plate S_1, has been arranged in the path of the pre-alignemnt beam b_1. This plate is shown in perspective in the left-hand part of Fig. 3. The Savart plate comprises two equally thick plano-parallel plates QP_1 and QP_2 of uniaxial birefringent crystals whose optic axes OA_1 and OA_2 make angles of 45° with the plano-parallel surfaces, the plates being rotated through 90° relative to each other. A radiation beam with a direction of polarization which is oriented at an angle of 45° relative to the optic axes of the Savart plate and which is perpendicularly incident upon the plano-parallel surfaces is split into an ordinary beam and an extra-ordinary beam in the first plate QP_1, which beams are transformed into an extra-ordinary beam and an ordinary beam, respectively at the interface between the first and the second quartz plate. This is because the optic axes of the plates QP_1 and QP_2 extend perpendicularly to each other. Two mutually parallel

beams $b_{1,1}$ and $b_{1,2}$ issue from the Savart plate S_1, which beams have mutually perpendicular directions of polarization and which are shifted laterally relative to each other over a distance which is a function of the thickness of the plates and the refractive indices. By a suitable choice of these parameters it is possible to ensure that the subbeams are shifted relative to each other over a distance which is equal to half the period of the phase grating P_1.

Further, a polarization-sensitive beam reflector PBS_1 is arranged in the path of the pre-alignment beam b_1. The selective reflecting surface PBP_1 of this prism functions as a polarization analyzer which only reflects radiation with a specific direction of polarization, namely at an angle of 45° to the optic axes of the Savart plate, to this plate S_1. After the two subbeams $b_{1,1}$ and $b_{1,2}$ have been reflected by the substrate and have traversed the Savart plate a second time, they are again incident on the prism PBS_1. The two mutually perpendicular directions of polarization of the two subbeams make an angle of 45° with the transmitting direction of polarization of the selective reflecting surface PBP_1. Each of these subbeams may be thought of as comprising two components of which the first and the second have a direction of polarization which extends parallel and perpendicularly, respectively to the direction of polarization of the prism PBS_1. The detector "sees" one beam with one direction of polarization in which no components can be distinguished.

The phase difference between the subbeams which emerge from the Savart plate S, depends on the refractive index n_o for the ordinary ray and n_e for the extraordinary ray and on the thicknesses of the plates QP_1 and QP_2 and the tilting of the Savart plate about an axis which extends transversely of the beam b_1 and perpendicularly to the plane of drawing. It is ensured that the subbeam $b_{1,1}$ and $b_{1,2}$ are in phase. Corresponding portions of the subbeams which have been reflected by substrate parts outside the phase grating are then also in phase. The beam which is formed through the combination by the Savart plate of the beam components which have been reflected by the substrate areas outside the phase grating then has the same direction of polarization as the beam which is incident on the substrate and the first-mentioned beam is not transmitted to the detector by the polarization-sensitive reflector PBS_1.

The effect of the grating is best explained if the subbeams $b_{1,1}$ and $b_{1,2}$ are assumed to consist of small beam portions of the size of the "hills" and "dales" of the phase grating. If a first beam portion of the beam $b_{1,1}$ is incident on a hill, the corresponding first beam portion of the beam $b_{1,2}$ will impinge on a dale of the phase grating. As a result of the grating structure the first beam portion of the beam $b_{1,1}$ is retarded relative to the first beam portion of the beam $b_{1,2}$, which retardation is a function of the depth of the grating dales or grooves. In order to obtain an optimum fine-alignment signal the grating grooves have been

given a depth of one quarter wave. This depth is also substantially optimal for the pre-alignment system. Said retardation is then 180°. Similarly, a second beam portion of the beam $b_{1,1}$ which impinges on a dale of the phase grating and a corresponding beam portion of the beam $b_{1,2}$ which is incident on a hill will exhibit a phase difference of 180° after reflection and after passage through the prism PBS_1. This applies to all the corresponding beam portions originating from the phase grating. In total the subbeams $b_{1,1}$ and $b_{1,2}$, if they originate from the phase grating are 180° phase-shifted relative to each other. In terms of directions of polarization this means that the direction of polarization of one of the subbeams has been shifted through 180° relative to the original direction of polarization, so that the direction of polarization of the beam which is composed of the two reflected subbeams has been rotated through 90° relative to the direction of polarization of the beam b_1 which has been reflected by the prism PBS_1. The part of the beam b_1 which has been reflected by the phase grating is transmitted to the detector D_1 by the beam splitter, so that this detector "sees" the phase grating as a bright surface against a black background.

As is shown in the inset in Fig. 3 the detector comprises four subdetectors D_{1a}, D_{1b}, D_{1c} and D_{1d}. The output signals of these detectors are proportional to the amount of radiation they receive. When these output signals are exactly equal, the grating P_1 is aligned correctly in the system. If the output signals of the detectors $D_{1,a}$, $D_{1,b}$, $D_{1,c}$ and $D_{1,d}$ are represented by S_a, S_b, S_c, and S_d the signal

$$S_x = (S_a + S_d) - (S_b + S_c)$$

will be a measure of the alignment in the x-direction and the signal

$$S_y = (S_a + S_b) - (S_c + S_d)$$

will be a measure of the alignment in the Y-direction. The output signals of the subdetectors are applied to an electronic processing circuit EP in which these signals together with the signals from the detector D_2 of the second imaging system are processed into control signals for the drive means DV for the substrate table WT'.

Instead of a Savart plate S it is also possible to use a Wollaston prism. As is shown in the left-hand part of Fig. 3 such a prism comprises two congruent prisms $WP_{1,a}$ and $WP_{1,b}$ of uniaxial birefringent crystals which have been combined to form a plano-parallel plate. The optic axes OA_a and OA_2 extend parallel and perpendicularly, respectively to the plane of drawing. A beam which is incident on one of the plane-parallel surfaces of the prism WP_1 and which has a direction of polarization which is disposed at an angle of 45° relative to the optic axes of the prism is split into two subbeams by the prism, which subbeams are polarized perpendicularly relative

to each other and make a small angle with one another. By a suitable choice of the thickness and refractive indices of the prism WP_1 it is possible to ensure that at the location of the grating the subbeams are shifted laterally relative to each other over a distance which is equal to half the grating period and each have the correct phase.

Preferably, the Wollaston prism is arranged in the first focal plane of the lens IL_1. After passage through this lens the two mutually perpendicularly polarized subbeams then extend parallel to each other. Moreover, the direct beams and the beams which are reflected by the substrate then traverse the prism at the same angles. If the Wollaston prism is arranged outside the first focal plane the beams will not be incident on the substrate parallel to each other, so that the distance between this substrate and the Wollaston prism becomes critical. Moreover, the reflected beams will then traverse this prism in a different way from the incident beams, so that the image of the phase grating formed on the detector will be of lower contrast.

In a tested version of the pre-alignment system described in the foregoing, a substrate can be pre-aligned with an accuracy of ±5 μm. The alignment range of this pre-alignment system is ±300 μm. A substrate which has been transferred to the pre-alignment station by mechanical transfer means can be positioned on the substrate table WT' by mechanical steps within said range.

Apart from polarization-sensitive elements, such as a Savart plate or a Wollaston prism, it is possible to employ other elements, such as a combination of semitransparent and fully reflecting mirrors, for splitting the beam b_1. The beam reflector PBS may then be a polarization-neutral beam reflector. Alternatively, the phase gratings may have grating periods which differ from those specified above. For the invention it is essential only that the distance between the subbeams is equal to half the grating period.

The illumination system comprises a lamp LA_1 and a condenser lens CL_1 which forms a beam of the radiation emitted by the lamp and images this lamp in the pupil of the lens IL_1, so that a maximum amount of light is available for pre-alignment. Just behind the condensor lens an aperture DP_1 is arranged which is imaged on the phase grating. This ensures that only an area slightly larger than the phase grating is illuminated. This method of illumination also ensures that hardly any stray light can reach the phase grating and that the detector signals contain hardly any noise.

The Savart plate or the Wollaston prism splits the pre-alignment beam into two subbeams which are mutually coherent and which after passage through the beam reflector PBS_1 can interfere with each other owing to this coherence. The subbeams themselves and the pre-alignment beams themselves, however, need not be coherent. Therefore, it is not necessary to employ a laser, which is monochromatic.

When a lamp LA_1 is used which emits a broad radiation spectrum, such as an incandescent lamp, a special beam-reflector prism PBS_1 must be used. A conventional polarization-sensitive reflecting prism has been designed for the components of a beam whose wavelengths are within a narrow band. The beam-reflecting layer of such a prism may comprise a plurality of sub-layers having thicknesses of the order of a quarter or half a reference wavelength. In accordance with the invention the prism PSB_1 which is employed in the pre-alignment system with broad-spectrum illumination has a beam-reflecting layer which comprises a first and a second set of sublayers, the first set acting as a beam reflector in a first wavelength range around a first reference wavelength and the second set acting as a beam reflector in a second wavelength range around a second reference wavelength. The entire layer comprising the two sets of sublayers can then reflect a beam with a broad range of wavelengths covering the two reference wavelengths.

As regards the Savart plate or the Wollaston prism it is not necessary to take special steps in view of the broad spectrum of the prealignment beam because these elements are substantially wavelength-independent. Particularly is this so if the radiation of this beam is situated in the near infrared range, which is preferred for the pre-alignment system.

So far, only the first imaging system, the left-hand system in Fig. 1, has been described. As will be apparent from Fig. 3, the second, right-hand imaging system is identical to the first one, so that the second system will not be described.

The signals from the composite detector D_2 of the second imaging system are applied together with the signals from the detector D_1, to the electronic processing circuit EP in order to be processed into control signals for the drive means DV. As is indicated in the plan view lower part of Fig. 3 the substrate table WT' is moved by means of three separately controlled drives DV_1, DV_2 and DV_3. The drive DV_1 moves the table in the X-direction and the two drives DV_2 and DV_3 provide the movements in the Y-direction. Owing to the separate control of DV_2 and DV_3 by means of the signals S_{y1} and S_{y2} the substrate table cannot only perform linear movements in the X and the Y direction, but can also rotate about a point, for example point R, thereby enabling angular alignment.

As is shown in Fig. 3 both illumination systems may comprise a beam separator BS_1 or BS_2. Those beam separators reflect a small portion, for example a few per cent, of the beams b_1 and b_2 via a reflecting prism RP_1 to a reference mark, such as cross-hairs GR. The position of the gratings P_1 and P_2 relative to the crosshairs can be made visible to the operator by means of a lens IL_3 and a reflecting prism RP_2, which image the cross-hairs and the superimposed images of the grating onto a television camera TVC which is coupled to a monitor MON.

The invention has been described for the projection of an IC pattern on a semiconductor

substrate. It is obvious that the apparatus described above may also be employed in other lithographic techniques where consecutively a plurality of masks have to be projected on a substrate and must be aligned very accurately relative to the substrate. An example of this is the manufacture of propagation patterns and detection patterns for magnetic domain memories. In the above description "IC pattern" should then read "propagation pattern" or "detection pattern" and "substrate" should read "layer of a magnetizable material".

Claims

1. An apparatus for imaging a mask pattern (c) on a substrate (w), which apparatus comprises a projection column provided with an optical imaging system (PL) and an optical fine-alignment system for aligning alignment marks on the substrate relative to an alignment mark in the mask, which apparatus further comprises a pre-alignment station (CA) for pre-aligning the substrate, and transfer means (WC) for transferring the substrate to a position beneath the projection column without disturbing the pre-alignment, characterized in that the pre-alignment station (CA) comprises two optical systems for imaging the two alignment marks (P_1, P_2) on the substrate onto two composite radiation-sensitive detectors (D_1, D_2), the combined output signals of the subdetectors of each detector (D_1, D_2) being a measure of the alignment of the corresponding alignment mark (P_1, P_2) relative to the detector.

2. An apparatus as claimed in Claim 1, intended for a substrate (W) whose alignment marks (P_1, P_2) are phase gratings, characterized in that the two imaging systems in the pre-alignment station (CA) are constituted by microscopes which image the phase gratings on the detectors (D_1, D_2) as amplitude structures.

3. An apparatus as claimed in Claim 2, characterized in that the microscopes are interference microscopes which each comprise an illumination system, an imaging lens (IL_1, IL_2) for the formation of a radiation spot (V_1, V_2) on a phase grating and for imaging said alignment marks (P_1, P_2) onto a detector (D_1, D_2) and a beam-splitting element for splitting the radiation from the illumination system into two subbeams $(b_{1,1}, b_{1,2})$ in such a way that at the location of the phase grating the subbeams are shifted relative to each other over a distance equal to half the grating period of the phase grating and for combining the two subbeams $(b_{1,1}, b_{1,2})$ which have been reflected by the phase grating.

4. An apparatus as claimed in Claim 3, characterized in that the beam-splitting element is a polarization-sensitive beam splitter and in that a polarization-sensitive beam reflector (PBS_1, PBS_2) is arranged between the illumination system and the imaging lens (IL_1, IL_2) for directing radiation of a specific direction of polarization towards the phase grating and for transmitting the radiation which has been reflected by the phase grating to the detector (D_1, D_2).

5. An apparatus as claimed in Claim 4, characterized in that the polarization-sensitive beam splitter is a Savart plate (S_1, S_2).

6. An apparatus as claimed in Claim 4, characterized in that the polarization-sensitive beam splitter is a Wollaston prism (WP_1, WP_2).

7. An apparatus as claimed in Claim 4, characterized in that the beam reflector (PBS_1, PBS_2) comprises a polarization-sensitive beam-reflecting layer (PBP_1, PBP_2) which comprises two sublayers which operate in two adjacent wavelength ranges.

8. An apparatus as claimed in any one of the preceding Claims, characterized in that the illumination system comprises a radiation source (LA_1, LA_2) followed by a condenser lens (CL_1, CL_2) which images the radiation source (LA_1, LA_2) in the pupil of the imaging lens (IL_1, IL_2) and a field aperture (DP_1, DP_2) arranged behind the condenser lens (CL_1, CL_2) which aperture (DP_1, DP_2) is imaged on the phase grating.

9. An apparatus as claimed in any one of the preceding Claims, characterized in that before the detector (D_1, D_2) a beam separator (BS_1, BS_2) having a low reflection coefficient is arranged in order to reflect a small portion of the radiation which has been reflected by the phase grating to a reference mark (G), and in that there are provided optical means for visually observing the reference mark (G) and the images of the two phase gratings superimposed on said reference mark (G).

Patentansprüche

1. Gerät zum Projektionskopieren einer Maske (C) auf ein Substrat (W), wobei das Gerät eine Projektionssäule mit einem optischen Abbildungssystem (PL) sowie ein optisches Feinausrichtsystem zum Ausrichten von Einstellmarken auf dem Substrat auf eine Einstellmarke in der Maske, weiter eine Vorausrichtstation (CA) zum Vorausrichten des Substrats und weiter Transportmittel (WC) zum Befördern des Substrats in einer Stell unterhalb der Projektionssäule ohne Beeinträchtung der Vorausrichtung enthält, dadurch gekennzeichnet, dass die Vorausrichtstation (CA) zwei optische System zum Abbilden der beiden Einstellmarken (P_1, P_2) auf dem Substrat auf zwei zusammengesetzte Strahlungsempfindliche Detektoren (D_1, D_2) enthält, wobei die kombinierten Ausgangssignale der Unterdetektoren jedes Detektors (D_1, D_2) ein Mass für die Ausrichtung der entsprechenden Einstellmarke (P_1, P_2) auf den Detektor ist.

2. Gerät nach Anspruch 1, zur Verwendung für ein Substrat (W), dessen Einstellmarken (P_1, P_2) Phasengitter sind, dadurch gekennzeichnet, dass die beiden Abbildungssysteme in der Vorausrichtstation (CA) durch Mikroskope gebildet werden, die die Phasengitter auf die Detektoren (D_1, D_2) als Amplitudenstrukturen abbilden.

3. Gerät nach Anspruch 2, dadurch gekennzeichnet, dass die Mikroskope Interferenzmikroskope sind mit je einem Beleuchtungssystem, einer Abbildungslinse (IL_1, IL_2) zur Bildung eines Strahlungsflecks (V_1, V_2) auf einem Phasengitter und zum Abbilden einer Einstellmarken auf einen Detektor (D_1, D_2) und einem Strahlspaltungselement zum derartigen Aufspalten der Strahlung aus dem Beleuchtungssystem in zwei Unterstrahlen ($b_{1,1}$, $b_{1,2}$) dass an der Stelle des Phasengitters die Unterstrahlen gegeneinander über einen Abstand gleich der halben Gitterperiode des Phasengitters verschoben werden, und zum Kombinieren der beiden Unterstrahlen ($b_{1,1}$, $b_{1,2}$) die durch das Phasengitter reflektiert wurden.

4. Gerät nach Anspruch 3, dadurch gekennzeichnet, dass das Strahlspaltungselement ein Polarisationsempfindlicher Strahlspalter ist, und dass eine Polarisationsempfindlicher Strahlreflektor (PBS_1; PBS_2) zwischen dem Beleuchtungssystem und der Abbildungslinse (IL_1, IL_2) angeordnet ist zum Richten der Strahlung mit einer spezifischen Polarisationsrichtung auf das Phasengitter und zum Übertragen der vom Phasengitter reflektierten Strahlung auf den Detektor (D_1, D_2).

5. Gerät nach Anspruch 4, dadurch gekennzeichnet, dass der Polarisationsempfindliche Strahlspalter eine Savart-Platte (S_1, S_2) ist.

6. Gerät nach Anspruch 4, dadurch gekennzeichnet, dass der polarisationsempfindliche Strahlspalter ein Wollaston-Prisma (WP_1, WP_2) ist.

7. Gerät nach Anspruch 4, dadurch gekennzeichnet, dass der Strahlreflektor (PBS_1, PBS_2) eine polarisationsempfindliche Strahlreflektierende Schicht (PBP_1, PBP_2) ist, die zwei Unterschichten enthält, die in zwei benachbarten Wellenlängenbereichen arbeiten.

8. Gerät nach einem oder mehreren der vorangehenden Ansprüchen, dadurch gekennzeichnet, dass das Beleuchtungssystem eine Strahlungsquelle (LA_1, LA_2) gefolgt von einer Kondensorlinse (CL_1, CL_2), die die Strahlungsquelle (LA_1, LA_2) in die Pupille der Abbildungslinse (IL_1, IL_2) abbildet, und eine hinter der Kondensorlinse (CL_1, CL_2) angeordnete Feldapertur (DP_1, DP_2) enthält, wobei die Apertur (DP_1, DP_2) auf das Phasengitter Abgebildet wird.

9. Gerät nach einem der mehreren der vorangehenden Ansprüche, dadurch gekennzeichnet, dass dem Detektor (D_1, D_2) ein Strahltrenner (BS_1, BS_2) mit einem niedrigen Reflektionskoeffizienten vorgeschaltet ist, zum Reflektieren eines geringen Anteils der Strahlung, die vom Phasengitter auf eine Referenzmarke (G) reflektiert wurde, und das optische Mittel zum visuellen Wahrnehmen der Referenzmarke (G) und der der Referenzmarke (G) überlagerten abbildungen der zwei Phasengitter vorgesehen sind.

Revendications

1. Dispositif pour reproduire une configuration de masque (C) sur un substrat (W), comportant une colonne de projection munie d'un système de reproduction optique (PL) et d'un système d'alignement fin optique pour l'alignement de repères d'alignement sur le substrat par rapport à un repère d'alignement présent dans le masque, appareil qui est en outre muni d'un poste de pré-alignement (CA) pour le pré-alignement du substrat et de moyens de transport (WC) pour le transport du substrat dans une position située au-dessous de la colonne de projection sans perturber le pré-alignement, caractérisé en ce que le poste de pré-alignement (CA) comporte deux systèmes optiques pour la reproduction de deux repères d'alignement (P_1, P_2) sur le substrat sur deux détecteurs sensibles à rayonnement composés (D_1, D_2), les signaux de sortie combinés des détecteurs partiels de chaque détecteur (D_1, D_2), constituant une mesure pour l'alignement du repère d'alignement correspondant (P_1, P_2) par rapport au détecteur.

2. Appareil selon la revendication 1 destiné à un substrat (W) dont les repères d'alignement (P_1, P_2) sont des trames de phase, caractérisé en ce que les deux systèmes de reproduction dans le poste de préalignement (CA) sont constitués par des microscopes, qui reproduisent les trames de phase sur les détecteurs (D_1, D_2) comme structures d'amplitude.

3. Appareil selon la revendication 2, caractérisé en ce que les microscopes sont des microscopes d'interférence, qui comprennent chacun un système d'éclairage, une lentille de reproduction (IL_1, IL_2) pour la formation d'une tache de rayonnement (V_1, V_2) sur une trame de phase et pour la reproduction de cette trame (P_1, P_2) sur un détecteur (D_1, D_2) et un élément diviseur de faisceau pour la division du rayonnement provenant du système d'éclairage en deux faisceaux partiels $b_{1,1}$, $b_{1,2}$, de façon qu'à l'endroit de la trame de phase, les faisceaux partiels soient décalés, l'un par rapport à l'autre, sur une distance égale à la moitié de la période de trame de la trame de phase et pour la combinaison des deux faisceaux partiels ($b_{1,1}$, $b_{1,2}$) qui ont été réfléchis par la trame de phase.

4. Appareil selon la revendication 3, caractérisé en ce que l'élément diviseur de faisceau est un diviseur de faisceau sensible à polarisation et qu'un réflecteur de faisceau sensible à polarisation (PBS_1, PBS_2) est disposé entre le système d'éclairage et la lentille de reproduction (IL_1, IL_2) pour diriger le rayonnement d'une direction de polarisation spécifique vers la trame de phase et pour la transmission du rayonnement réfléchi par la trame de phase vers le détecteur (D_1, D_2).

5. Appareil selon la revendication 4, caractérisé en ce que le diviseur de faisceau sensible à la polarisation est une plaque de Savart (S_1, S_2).

6. Appareil selon la revendication 4, caractérisé en ce que le diviseur de faisceau sensible à polarisation est un prisme de Wollaston (WP_1, WP_2).

7. Appareil selon la revendication 4, caractérisé en ce que le réflecteur de faisceau (PBS_1, PBS_2) comporte une couche réflectrice de faisceau sensible à polarisation (PBP_1, PBP_2), comprenant

deux couches partielles qui fonctionnent dans deux gammes de longueurs d'onde voisines.

8. Appareil selon l'une des revendications précédentes, caractérisé en ce que le système d'éclairage est constitué par une source de rayonnement (LA_1, LA_2) suivie d'une lentille de condenseur (CL_1, CL_2) qui reproduit la source de rayonnement (LA_1, LA_2) dans la pupille de la lentille de reproduction (IL_1, IL_2) et un diaphragme de champ (DP_1, DP_2) qui est disposé derrière la lentille de condenseur (CL_1, CL_2) et qui est reproduite sur la trame de phase.

9. Appareil selon l'une des revendications précédentes, caractérisé en ce que devant le détecteur (D_1, D_2 est disposé un séparateur de faisceau (BS_1, BS_2) présentant un faible coefficient de réflection afin de réfléchir une petite partie du rayonnement réfléchi par la trame de phase vers un repère de référence (G) et que des moyens optiques sont prévus pour l'observation visuelle du repère de référence (G) et les reproductions des deux trames de phase superposées sur ledit repère de référence (G).

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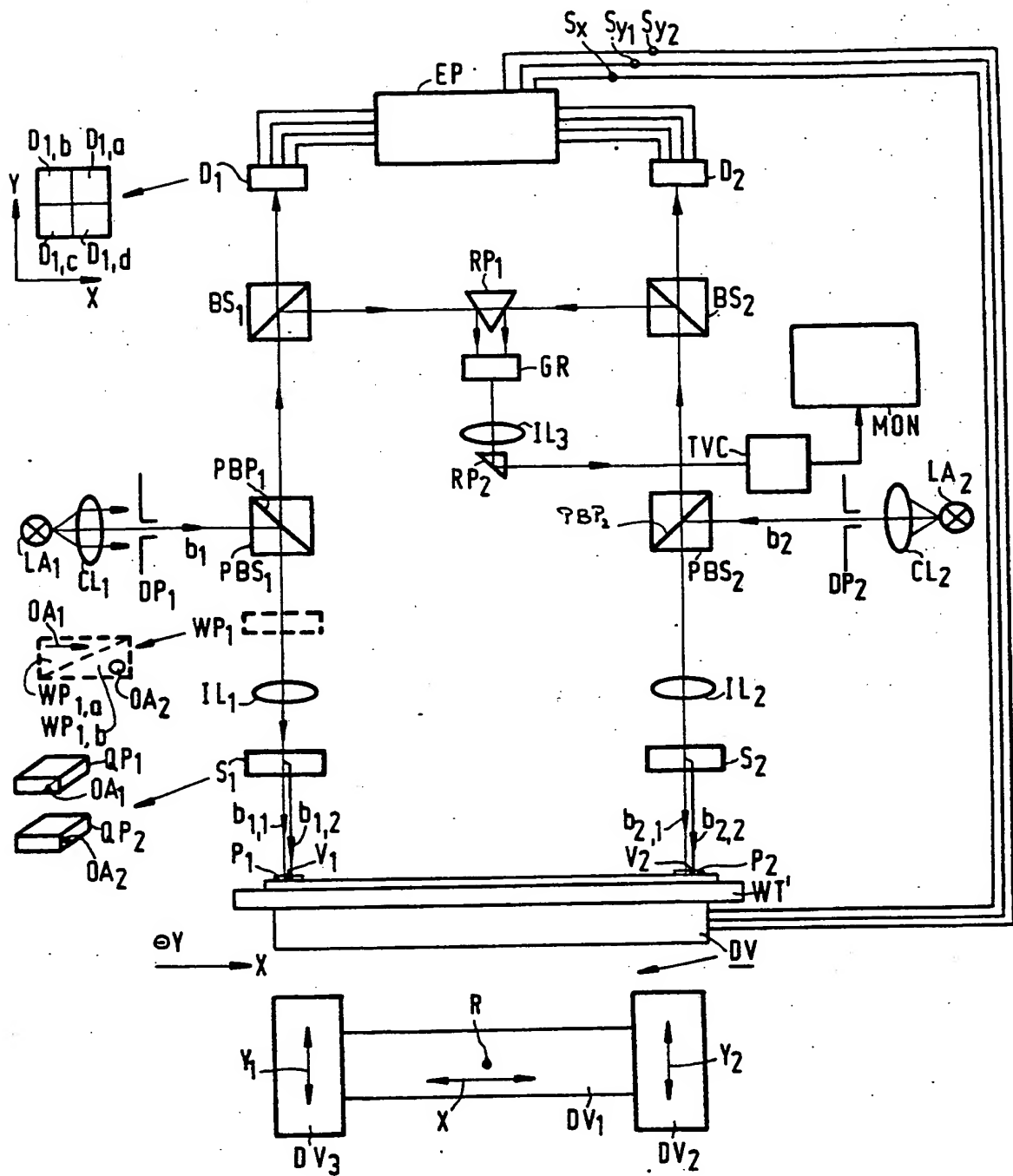10

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FIG.1

FIG.2

FIG. 3